AN INDEX NUMBER OF PRODUCTION[1]

The fluctuations in the physical volume of production must be measured before they can be interpreted or controlled. The nature and causes of the increase in production, the relative significance of the various sources from which products are drawn, the extent of the waste involved in the decrease of output during periods of industrial depression are matters to be determined quantitatively. These changes are the outcome of influences so diverse that in order to explain them casually the date and the degree of the fluctuations must be specified. To make these measurements is the purpose of an index number of production.

The need for such measurements is so evident and the use of index numbers of prices so common that the question arises why index numbers of production were not made long ago. One explanation lies in the kind of limits imposed upon inquiries by the traditions of economic theory, limits which left the study of production in terms of physical units outside the pale. When the economist regarded production as a technological process it became to him a mass of bewildering details. Technology seemed to comprise fields of specialized knowledge either beyond the comprehension of an economist or at least beyond the reach of his theoretical formulations. The variety and unfamiliarity of the units of measurement, the rate of change in methods of production, the scale and complexity of industrial operations discouraged any search for generalizations. Such a field, he concluded, might better be left to the specialists, to the technicians of industry. So far as economic theory was concerned, therefore, the cause and consequences of the growth of technology remained the great unknown, and conclusions from deductive arguments were protected by the phrase "assuming the state of the industrial arts to remain the same." In the meantime, the problem of properly managing our industrial resources suffered from the faults characteristic of all merely specialized thinking.

A further reason why the economist shunned the analysis of the production process in terms of physical units is that, in common with the business community, he believed the facts could be adequately stated and handled in pecuniary terms alone. He congratulated the community on having a common denominator of money in which to do its thinking. Like the accountant he took inventories in terms of dollars and cents and in the absence of any specific knowledge about the changes in the volume of goods and of equipment he ordinarily assumed a co-

[1] A paper read at the Thirty-third Annual Meeting of the American Economic Association, held at Atlantic City, December 28, 1920. In the collection of the statistics and in the computation of the index numbers the writer has had the assistance of Miss Caroline Emerson and Miss Stella Stewart.

incidence between statements of money values and the underlying industrial quantities. Statements of national income and of national wealth in money terms may be given a clear meaning, but to fund these items and measure them in money terms alone is to obliterate distinctions which must be preserved if we are to understand and administer industrial processes. No question need be raised about the usefulness of this pecuniary accountancy for business purposes; likewise there can be no question about the need for an industrial accountancy for industrial purposes.

A system of industrial accountancy cannot be confined to recording the activities of a single plant; it must measure the flow of products from great groups of industries. As industrial economists we are interested not merely in the management of single factories; we are concerned also with the effectiveness of the correlation between industries and groups of industries. Fields, mines, factories, and railroads working together under a coördinated plan make up the industrial system; their total product is largely determined by the effectiveness with which they come into gear with one another. What is needed, for purposes of measurement and for guidance, is a system of index numbers of production so constructed as to reveal the behavior of the industrial system in its parts and as a whole.

Experience in the construction and use of index numbers of prices indicates the methods to be used in measuring the changes in the level of production.[2] In making a production index one is confronted with difficulties similar to those met in constructing a price index. There is the problem of selecting the commodities to be included, the choice of base periods, and the problem of weighting the selected samples in such a way that each will have its proportionate influence upon the final result. To an explanation of how these problems were dealt with in the construction of the present index number of production, we may now turn.

[2] The work of the Price Section of the War Industries Board was especially useful in making a choice of methods of construction. In addition to the index of prices, an index was constructed under the direction of Professor Wesley C. Mitchell, measuring the fluctuations in the physical volume of production for the period 1913 to 1918. (*History of Prices During the War. Summary.* War Industries Board Price Bulletin, No. 1, pp. 44-46.) Also Mr. Wolman, as chief of the Division of Statistics of Production, made it evident during the war that the problem of production could be handled statistically. Out of the war experience, in fact, there came a new recognition of the desirability of measuring the physical volume of production. Mr. Edmund E. Day, working from much the same data as those used in the present study, but by a somewhat different method, has also just completed the construction of an index number of production. (*The Review of Economic Statistics,* September-December, 1920, The Harvard University Press.)

This index number is based upon a total of 91 different series of commodities.[3] For two thirds of these, production figures are available for every year from 1890 to 1919, and for the remainder the information is available beginning in 1904. The following table shows the number of commodities in each of the groups and sub-groups:

All Commodities	91	Materials	39	Manufactures	50
Materials	39	Farms	16	From farm products	22
Manufacture	50	Mines	13	" mineral products	23
Transportation	2	Forests	7	" forestry products	4
		Fisheries	2	" fishery products	1

Of the 50 different series under Manufacture, 14 are not manufactured products, but are estimates of the amount of certain materials used in manufacture. In the absence of information about the production of cotton cloth, for example, the figures showing how much cotton was used in manufacture in a given year were taken as indicating the production of cotton textiles in that year. In other series, imports of certain materials were taken as indicating the production of the commodities into which they entered. This method of estimate was not used where there was reason to believe that the accumulation of stocks from one year to the next was an important factor.

The production statistics of certain commodities were excluded from the index. The figures for the production of distilled and fermented liquors, for example, were not used because they are for fiscal years while the other data are for calendar years. The decision against these series was made only after fair trial, and when it became evident that production figures for the year ending June 30 could not be used as equivalent to the production for the year ending December 31, if the purpose were to make year to year comparisons.

The figures for the production of freight cars, passenger cars, and locomotives, which are available for the entire period from 1890 to 1919, were also excluded because during that period the type of car and of locomotive underwent great change. Though today they pass by the same names they are in reality quite different products. The locomotive increased from the average weight of approximately 40 tons to 89.5 tons. The average capacity of freight cars almost

[3] A list of the commodities arranged by groups, and a table of the index numbers are presented on pages 67-69. The sources of information were for the most part official publications. Among these were the bulletins issued by the various bureaus of the Department of Agriculture, the Geological Survey, the Bureau of the Census, the Bureau of Fisheries, Bureau of Internal Revenue, Bureau of Foreign and Domestic Commerce, and the Interstate Commerce Commission. Other sources were the publications of such commercial organizations as the American Iron and Steel Institute, the New York Board of Trade, and the New Orleans Board of Trade.

doubled. Numbers of freight cars and of locomotives, therefore, are not satisfactory statistical units to use in a measurement of changes in production over long periods. It is hoped later, however, to make use of these figures in a study of the changes from year to year in the output of equipment.

In some instances the series included are the result of estimates. In the live stock industry, for example, a large number of estimates were necessary and the results are only partially satisfactory. From 1907 to 1919 the figures for meat production are based upon the number of animals inspected for slaughter, and a further estimate for the slaughter which did not come under federal inspection.[4] Prior to 1907 the figures for inspected slaughter cannot be used as indicating meat production. For the earlier years, therefore, the estimates are based on the differences between receipts and shipments of cattle, hogs, and sheep in the fifteen principal markets. These markets include the great packing centers. A comparison of receipts minus shipments with the figures of inspected slaughter during the period when the latter are trustworthy, shows that though the degree of fluctuation is not the same yet they agree in the direction of change. In the absence of anything better, therefore, the differences between receipts and shipments were used as indicating the general trend of meat production.

Another industry which required calculation, but not estimates, was Transportation. Here it was necessary to convert figures for ton-miles and passenger-miles from fiscal years to calendar years. The method of conversion consisted, first, in pro-rating the fiscal year total of ton-miles among the months, the basis of the distribution being the percentage of the annual freight revenue received each month; second, in adding up the ton-miles by calendar years. The same method was used to convert fiscal year totals for passenger-miles into calendar year totals. This was done for each year from 1907 to 1916, when the Interstate Commerce Commission began publishing the figures by calendar years. The information necessary to make the conversions was not available back of 1907, and consequently from 1890 to 1907 the figures for transportation service are for fiscal years.

There are other estimates involved in establishing the 91 series but this is not the place to set them forth in detail. The instances that have already been given are typical of the difficulties with which one is confronted in taking the initial step of selecting the commodities to be included.

[4] From 1911 to 1918 the figures used are those furnished by the Food Administration, which make allowance for the seasonal fluctuation in the weight of live stock. See *Production of Meat in the United States and its Distribution during the War,* by Stephen Chase, Food Administration, 1919.

In view of the various degrees of importance of the different commodities included in the index a system of weighting must be used. Weights are provided in order that each commodity, standing as the representative of part of a sequence of production, may exercise upon the index number an influence proportionate to its importance. For the purposes of the present method of weighting the production process is regarded as consisting of a series of sequences, each starting from some initial raw material, and passing through various stages to the finished product. It is important in such a plan to avoid duplication in those series which have a large number of representatives, and to give wherever possible the full value of a sequence to such representatives as can be found.

In the beginning, therefore, the so-called raw materials produced at farms, mines, forests, and fisheries are weighted according to their value at the place of production. The average farm values, for example, in the base year, are taken as indicating the importance of each of the materials from farms. Each manufactured commodity is then weighted according to the "value added" to it by manufacture, that is, the difference between the initial value of the constituent materials in the base year and the value of the commodity at that particular stage of manufacture in the same year. So, for instance, coke is included only at the difference between its value and the cost of the coal used in its manufacture, and structural steel only at the value by which it exceeds the steel ingot from which it was rolled. Thus the value of the sequence as a whole is distributed among its various representatives. In cases where there is a single series it carries the weight for the whole sequence. For instance, "wool, used in manufacture," is weighted for all the products manufactured from wool. In deciding upon the weight to be assigned Transportation it was necessary to estimate the "value added" by the transportation service and to divide it between freight and passenger service. The "value added" was estimated by subtracting from the operating revenues the cost of materials, including an allowance for depreciation chargeable to operating expenses. Various methods of estimate have necessarily been used in determining the weights, but the objective has remained the same—that is, the assignment to each commodity of a value which when it was added to the values assigned other commodities in the same sequence would keep that sequence in proper proportion to other sequences.

The results of the system of weighting, so far as it affects the degree of influence exercised by each group upon the All Commodities index, is indicated by the following table. The figures are percentages showing the distribution among the various groups of the total pro-

duction aggregates (production in physical units multiplied by weights) for the year 1914.

All Commodities	100	Materials	51	Manufacture	35
Materials	51	Farms	39	From farm products	21
Manufacture	35	Mines	9	" mineral products	13
Transportation	14	Forests	3	" forestry products	1

The year 1914 has been used as a base year for purposes of weighting, because of the information made available in that year by the Census of Manufactures. The question arises, in view of the business conditions which prevailed during 1914 whether that is a satisfactory year to use as a base for weighting. It has been thought that the depression in that year may have affected industries unevenly. The following table, which shows the percentage distribution of the total "value added by manufacture" among the various groups of industries, for four successive census years, may be used in determining that question.

PERCENTAGE OF TOTAL "VALUE ADDED BY MANUFACTURE"

Group	1914	1909	1904	1899
All Industries	100.0	100.0	100.0	100.0
Food and products	10.0	8.8	8.6	8.6
Textiles and products	14.4	15.4	14.3	15.2
Iron and steel and products	14.8	16.0	16.0	16.9
Lumber and manufactures	8.5	10.2	11.2	10.9
Leather and products	3.6	3.8	3.9	3.8
Paper and printing	8.7	8.5	8.8	8.2
Liquor and beverages	5.3	5.7	5.7	6.0
Chemicals and products	7.2	7.0	7.0	6.4
Stone, clay and glass products	3.8	4.1	4.3	3.8
Non-ferrous metals and products	4.0	4.1	4.2	4.5
Tobacco manufactures	2.9	2.8	3.3	3.5
Vehicles for land transportation	4.5	3.0	2.3	2.6
Railroad repair shops	3.0	2.6	2.6	2.4
Miscellaneous	9.3	8.0	7.9	7.2

The table indicates that in spite of changes in prices, methods of production, and conditions of business, there is a remarkable degree of constancy among various groups of industries with respect to the percentage of the total "value added by manufacture" contributed by each group. During the entire period each of the fourteen industries occupies approximately the same rank with regard to the others. Such changes in relative importance as actually took place between 1909 and 1914 are not due exclusively to the character of the business conditions in 1914. Five years elapsed between the census takings, and even if business conditions had been the same in the two years, there would have been some shifting in industry. Since the same general propor-

tions are maintained throughout the period it seems satisfactory for purposes of the present system of weighting to use figures from the census of 1914.

One further technical point needs to be noted. When the list of commodities was revised in 1904 to include the new commodities for which production statistics had become available by that year it was necessary to adjust the production aggregates for the years 1890 to 1903 during which those commodities were not included. This adjustment was made simply by raising the series of aggregates for the earlier years to the level of the aggregate of 1904 with the new commodities included. Since the index measures only the relative changes this adjustment does not affect in any way the fluctuations of the index in the earlier years, and it makes possible the inclusion of commodities which could not otherwise have been used.

This statement of methods may now be brought to a close by reciting briefly the steps in the computation of the index number. These computations consist for a single year in multiplying the production of each commodity in that year by the assigned weight, and then adding these results to obtain the production aggregate for that year. The weights, of course, are kept constant so that in the calculations for the successive years the only variable is the production in physical units. When this is done for each of the thirty years the result is a series of total production aggregates and series of sub-totals for the groups which may be turned into relatives on any base desired. The base selected for the index numbers here presented is the average production aggregate for the three pre-war years; that is, the average of the production aggregates for the years 1911 to 1913 is taken as 100.

We may now consider the fluctuation of these index numbers as shown by the charts and comment briefly on the meaning of those fluctuations. Chart I furnishes a comparison of the changes in the level of production with the changes in the level of prices. The chart is a graphic representation of the All Commodities index of production and the All Commodities index of prices as given in the table on page 68. Perhaps the most apparent fact is that prior to the war inflation the volume of production rose at a rate more rapid than the level of prices. During the period from 1890 to 1914 the index of production rose from 45 to 101 while the index of prices rose from 82 to 101. But during the next four years, that is from 1914 to 1918, the level of prices rose 99 per cent above the pre-war level, while production increased 23 per cent.

This increase in production looks small compared with the rise in prices, yet it is in itself a remarkable fact. It is still more remarkable that in an earlier period of the same length production increased at an

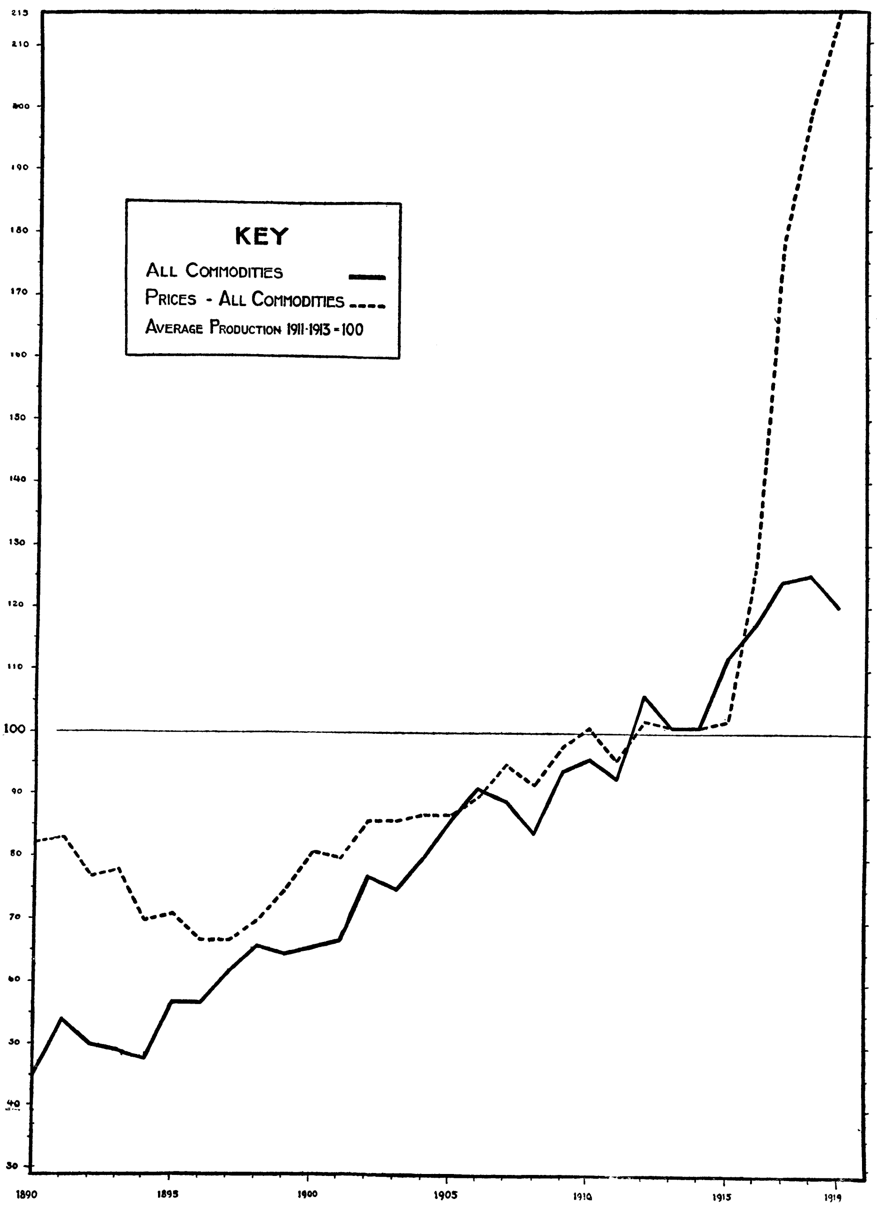

CHART I.—WEIGHTED INDEX NUMBERS OF PRODUCTION AND OF PRICES
Index of production includes 91 series; index of prices is that compiled by Bureau of Labor Statistics. Base periods, 1911-1913 = 100.

even more rapid rate. From 1908 to 1912 the increase was 26 per cent. Both periods begin in a year of depression and end at a peak of industrial activity. The increased production of the war period, therefore, was not due merely to a patriotic effort to increase output, but was made possible by the industrial slack which existed in 1914.

The sources of this increased production of the war period become more evident from an analysis of the curves on Chart II. This chart presents the index numbers of Total Materials, Total Manufactures, and Transportation. From 1914 to 1915 there is a marked increase in all three. After 1915, however, Materials does not rise above the point reached in that year, while both Manufacture and Transportation make great advances in 1916 and rise again in 1917. Some conception of the magnitude of the task performed by the railroads while under government operation is apparent from the chart. At a time when the aggregate production of the country was increasing 24 per cent, the burden upon the railroads increased by 41 per cent, and this increased traffic was carried without substantial increases in equipment.

A comparison of the curves for the entire period of thirty years shows the relative rates of increase of the three groups. Transportation ranks first in the rate of growth, manufactured products second, and materials third. There is a similarity in the movement of the Transportation index and the index of Manufactures, especially over the period where both are on a calendar year basis. Prior to 1906 the effect of using fiscal year figures for Transportation can be noted. The use of totals for the year ending June 30, makes the changes come a year later than the corresponding changes in Manufacture.

We speak of the rate of growth in production, but the increase has not been a steady advance. The tendency of prices and production to keep step is especially significant in those periods when the volume of production falls off because of the condition of the markets. As a single instance, take the depression year of 1908. A striking fact in that year is the divergent movement of Materials and of Manufacture. The output of materials actually increased while the production of manufactured goods decreased. The explanation for this divergence seems to be that the production on farms is not under the influence of market conditions to the same degree as production at mines and factories. In 1908 the production of corn and wheat and hay and hogs and cotton was greater than in 1907. But the production of bituminous coal was 62,000,000 tons less, a decrease of 16 per cent; the output of steel was 9,300,000 tons less, a decrease of 40 per cent. Though the cotton crop was greater by 19 per cent, there was less cloth produced, because the cotton actually used in manufacture decreased 9

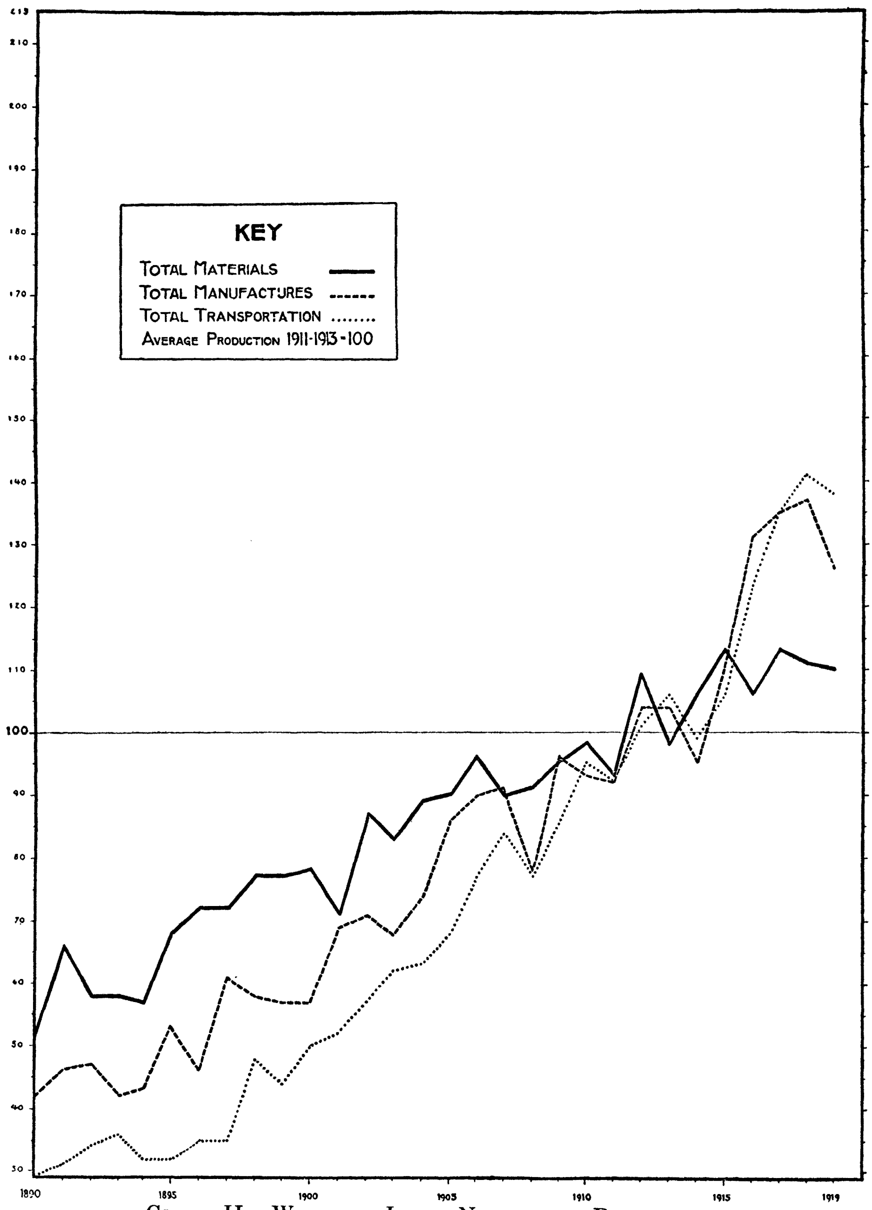

CHART II.—WEIGHTED INDEX NUMBERS OF PRODUCTION

Index of Materials includes 39 series; Manufacture includes 50; Transportation, 2. Base period, 1911-1913 = 100.

per cent. The farms were busy, but the textile mills and steel plants were idle.

Perhaps these figures in physical units seem unfamiliar and you prefer to count the loss in money values. Assuming, then, that in 1907 the national income was $30,000,000,000, whatever that may mean, the decrease in total production in 1908 of 5.36 per cent cost the country over $1,600,000,000. I would add other items to this total, but I know of no way to include in the reckoning the costs in worry and privation borne by men out of work and by their families. This decrease in production occurred not because there was a shortage of materials nor a lack of equipment, nor because there were no men willing to work, but because there was not an adequate organization for bringing these elements together for the purpose of producing goods.

Such, approximately, were the losses due to the depression of 1908. We are now entering another depression, the duration and intensity of which no one can predict with certainty, and as a community we seem to count the losses as inevitable. To regard waste of such magnitude as the necessary accompaniment of business cycles and to give up the problem of stabilizing the level of production is to confess our incompetence.[5] Instead of such confession, however, one ordinarily hears complaints about workmen soldiering on the job. For the analysis of such problems we need a re-introduction into economic theory of the concept of waste, and we need the tools to locate and to measure it.

In conclusion, the index numbers here presented are not to be regarded as definitive and final. They are in the experimental stage and are subject to additions and betterments whenever a way of improvement is suggested. As information concerning the output of other commodities becomes available they may be included in the index. The present method of construction permits their inclusion without breaking the continuity of the index. The gathering of such additional information and the testing of the adequacy of existing data are tasks which must not be slighted. In the present state of the statistics of production such work is more important than the choice between alternative methods of organizing the information after it is once collected. So long as whole industries are omitted from the index, such as the building industry, the work of measuring the changes in the volume of production is little more than begun. Certainly the extent of agree-

[5] One plan for stabilizing production was proposed by Professor David Friday a year ago, while there was still a chance of preventing the present decline in output. See article in *Journal of Political Economy,* February, 1919, entitled, "Maintaining Productive Output—A Problem in Reconstruction." Whatever the merits of his particular proposal may be he has at least recognized the nature and seriousness of the problem.

INDEX NUMBERS OF PRODUCTION
(Average production 1911-1913 = 100)

Years			Materials		Manufacture			Transportation	Prices[1]
	All commodities	Total materials	Farm materials	Minerals	Total manufacture	Manufactured from Farm products	Manufactured from Mineral products	Total transportation	All commodities
1890	45	52	57	30	42	61	17	29	82
1891	54	66	73	32	46	68	16	31	83
1892	50	58	62	34	47	67	19	34	77
1893	49	58	63	34	42	61	16	36	78
1894	48	57	62	33	43	61	17	32	70
1895	57	68	74	37	53	75	23	32	71
1896	57	72	79	39	46	65	20	35	67
1897	62	72	78	40	61	87	26	35	67
1898	66	77	84	43	58	78	32	48	70
1899	65	77	82	48	57	70	38	44	75
1900	66	78	82	52	57	74	35	50	81
1901	67	71	73	55	69	87	44	52	80
1902	77	87	92	57	71	87	50	57	86
1903	75	83	86	64	68	83	49	62	86
1904	80	89	94	66	74	91	52	63	87
1905	86	90	94	74	86	98	71	68	87
1906	91	96	100	77	90	97	83	77	90
1907	89	90	89	86	91	98	82	84	95
1908	84	91	95	79	78	94	57	77	92
1909	94	95	95	87	96	102	88	86	98
1910	96	98	98	94	93	95	92	95	101
1911	93	93	93	93	92	97	85	92	96
1912	106	109	111	101	104	102	107	101	102
1913	101	98	96	106	104	101	108	106	101
1914	101	106	108	100	95	103	85	99	101
1915	112	113	116	108	111	110	110	106	102
1916	117	106	101	123	131	117	145	123	126
1917	124	113	110	131	135	118	148	135	178
1918	125	111	108	132	137	126	145	141	199
1919	120	110	112	112	126	120	118	138	215

[1] Bureau of Labor Statistics index converted to base 1911-1913 = 100.

ment among the index numbers of production which have so far been constructed is no more significant than the fact that they all have the common shortcoming of omitting the building industry. Any interpretation of these index numbers must begin with a recognition of those industrial activities which are now unmeasured and omitted. The increase in precision will be in proportion to the attention paid these present shortcomings.

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LIST OF COMMODITIES INCLUDED IN INDEX OF PRODUCTION

MATERIALS FROM

I FARMS:

Apples
Barley
Corn
Cotton, raw
Hay
Oats
*Peaches
Potatoes, white
*Potatoes, sweet
Rice
Rye
Sugar, beet
Sugar, cane
Tobacco
Wheat
Wool, raw

II MINES:

Coal, anthracite
Coal, bituminous
Copper
Gold
Iron, ore
Lead
Petroleum
Pyrites
Quicksilver
Salt
Silver
*Sulphur ore
Zinc

MANUFACTURE

V MANUFACTURED FROM FARM PRODUCTS:

Coffee, used in manufacture
*Cotton, used in manufacture
Cotton seed
Cotton seed oil
Cake and meal, cotton
*Hulls, cotton
*Linters, cotton
Hemp; Manila, used in manufacture
Jute, used in manufacture
Sisal grass, used in manufacture
Molasses
Cigarettes
Cigars
Tobacco and snuff
Wheat, used in manufacture
*Beef
*Mutton
*Pork
*Hides, cattle
*Skins, sheep
Silk, used in manufacture
Wool, used in manufacture

VI MANUFACTURED FROM MINERAL PRODUCTS:

*Brick, common
*Brick, front
*Brick, vitrified
Cement
Coke
Copper, used in manufacture
Gold, used in manufacture
Pig iron
Steel ingots and castings
*Bars, merchant
Plates and sheets
Rails
*Structural shapes
*Skelp
*Wire rods
*Tin plate
Nails, cut
Nails, wire
Lead, used in manufacture
*Lime
Silver, used in manufacture
Tin, used in manufacture
Zinc, used in manufacture

III FORESTS:
- *Douglas fir
- *Hemlock
- *Oak
- *Spruce
- *Western yellow pine
- *White pine
- *Yellow pine

IV FISHERIES:
- *Cod
- *Haddock
- *Mackerel

VII MANUFACTURED FROM FOREST PRODUCTS:
- *Lath
- *Shingles
- Turpentine
- Rubber, used in manufacture

VIII MANUFACTURED FROM FISHERY PRODUCTS:
- *Salmon, canned

TRANSPORTATION

IX TRANSPORTATION:
- Freight—ton miles
- Passenger—passenger miles

* Included from 1904-1919.

DISCUSSION

CARL SNYDER.—In his comprehensive work on *Business Cycles,* 1913, Mitchell pointed out as among the first requisites for a larger understanding, the need of an index of the physical volume of trade. An inquiry undertaken by the writer showed that a reliable index of the volume of trade was much more difficult of compilation than an index of production in the leading lines of industrial activity, including, of course, agriculture. But the preparation of this latter revealed that an index of production is likewise probably the most accurate index of trade that we have. There is probably no great variation in trade aside from the variations in product. That is to say, what is produced is very largely consumed year by year; and there appears to be very rarely any accumulated surplus of moment.

Probably the best general index of trade that we had was the bank clearings outside of New York City. It had been supposed that these grew more rapidly than the general trade of the country, and also that they were very greatly affected by periods of intense speculative activity, like those of last year.

Prior to 1890, these clearings did grow very rapidly, owing to the rapid extension of the clearing house system, and the actual number of clearing houses. Subsequent to 1890 these clearings, corrected for price changes by dividing by the Bureau of Labor's index of commodity prices, show a fairly consistent growth at the average rate of close to 4 per cent per annum. The preparation of an index of production revealed that the average annual increase in the product was practically the same. Periods of speculative activity do show a sensible variation between the two indices; but only for a brief time.

It is remarkable that, until the present year, there had been no serious effort to measure the total national product or its rate of growth over an extended period of years. This was the more regrettable, for it left the field wide open for the most conflicting views as to whether production in a given year was low or high, labor inefficient or the reverse, whether there was a scarcity of goods, and so on.

Professor Kemmerer had made an excellent beginning in his *Money and*